IDENTIFICATION OF POLYGONAL PATTERNS ON VENUS USING MATHEMATICAL MORPHOLOGY. P. Moreels and S. E. Smrekar, NASA Jet Propulsion Laboratory, Geophysics and Planetary Geoscience Element (MS183-501, 4800 Oak Grove Drive, Pasadena, CA 91109. Pierre.Moreels@jpl.nasa.gov, Ssmrekar@jpl.nasa.gov)

Introduction: Many images in the Magellan SAR database show small (typically 1-3 km in diameter) polygonal features (fig. 1) on the surface of Venus [1][2], possibly related to climatic changes that occured in the past [2][3]. Although some of these regions have already been reported, we believe their abundance may be much higher. We developed a detection and recognition model to fully automatize the identification of these polygonal patterns. Our segmentation model is based on a modified watershed algorithm [4]. Saliency of the contours [6] is used to prevent the oversegmentation that usually goes along with the watershed method, and provides a good invariance to radar noise. The analysis is performed on two different scales for better match with human observations and for a reduced computational cost. Properties like area, dimensions or orientation of the patterns are then precisely calculated, this information on the characteristics of polygons can then be used to assess their origin. We also build maps of the distribution and properties of those polygons.

Watershed segmentation [4][5]: The watershed method is a powerful algorithm of mathematical morphology for segmentation of images. The absence of preferred orientation and of required a priori knowledge make its use relevant for application to Venus' polygonal terrains and preferable to methods based on Markovian fields applied to detection of road networks on Earth [7]. The image is considered as a field of mountains, the grey level representing the altitude (a low grey level, characterizing a dark pixel, has a low altitude, whereas a higher grey level, or bright pixel, has a higher altitude). The watershed method pours imaginary water in this landscape, resulting in ponds growing from local minima of the grey level. Every time two of these regions reach each other, a dam is erected between the basins of catchment. The resulting set of dams forms the frontiers between polygons. Unfortunaltely the raw algorithm leads to oversegmentation, every local minimum, even small and due to noise, being the origin of a new region. Classic preprocessing like gaussian filtering of the image is also of little use in removing radar noise (speckle) since it is multiplicative, not additive noise.

Dynamics of the contours : To avoid oversegmentation, we use the dynamics of the contours, as defined in [6]: before processing the watershed, rain falls on the "greylevel landscape". No matter what the altitude is, ponds are created from the local minima, the surplus of water falling from the settle points into lower regions (fig.2). This step eliminates small peaks due to noise, and is insensitive to large dark or bright stripes. The amount of "rain" that is poured in the basins is a parameter controlling the size of the patterns that will be obtained with the watershed. It is set automatically, depending on average grey level and standard deviation of the initial and prefiltered images obtained by erosion, dilation and LUM filtering [8].

Two-scale analysis: The whole flooding process is performed at two different scales. This leads to a good match with human observations (fig 3). Patterns catching the attention can be small and have a high grey-level, or bigger, with lower grey-level. A first run is performed at a coarse resolution, detecting only the most apparent features in the image. If the image contains no polygonal faults, the lines obtained with the watershed algorithm form regions which have a highly variable interior brightness, as well as irrelevant fault segments number and lengths, and the image is rejected. When it is kept, a second run provides fainter complementary patterns and lines that were not detected previously, such as lines that are not immediately apparent to a human observer. The use of the coarse resolution is also effective in terms of computation cost, since the slow high-resolution process is not executed when the image is rejected.

Region analysis: The edges of the detected regions are then identified. Each polygon is characterized by its set of edges, and properties like area, diameter, elongation, are precisely calculated. In particular we obtain for the frame displayed in (fig. 1) a mean diameter of 2.6 km, in agreement with [1] and [2]. Orientation of the edges is also computed (fig 4). In some cases, particularly when a main set of delineations is present in the picture, the analysis reveals secondary preferred orientations that human observers would not detect at first glance. A polygonal approximation of the contours is also computed, and the average number of edges per polygon is obtained. (5-6 edges per polygon in fig. 4)

As the patterns detected by our algorithm are quite small (2-3 km) in the processed frames, the best matches with visually detected segments are obtained when using full-resolution frames (1024×1024 pixels at 75m/pixel, i.e. 77×77 km^2.) We also processed successfully half-resolution frames, obtained with median filtering for a good insensitivity to radar speckle. Elaboration of maps of large areas of Venus showing properties of the detected polygons is currently under way. Our program can be used whenever regions display closed patterns, we obtained good results on Galileo Europa images showing meshes of lines, and at a different scale (~300 meters in diameter) on Mars MGS images of patterns in impact craters.

References: [1] Johnson C. L. and Sandwell D. T. (1992) *JGR, 97, 13,601-13,610.* [2] Anderson F. S. and Smrekar S. E. (1999) *JGR, 104, 30,743-30,756.* [3] Solomon S. C. et al. (1999) Science, 286,5437,87-90. [4] Vincent L. (1990), PhD thesis, *Ec. des Mines, Paris, 05/90.* [5] Schmitt M. and Matioli J. (1993), Morphologie Mathématique, *Masson, 12/93.* [6] Najman L. and Schmitt M. (1996) *IEEE Trans. on pattern anal. & mach. intell., 18-12, 1163-1173..* [7] Tupin F. et al. (1998) *IEEE Trans. on geosc. & remote sens. 36,2,434-453.* [8] Hardie R. C. and Boncelet C. G. (1993) *IEEE Trans. on sign. proc. 41,3 1061-1076.*

Fig 1: Image F-MIDR 60N132 framelet 31.

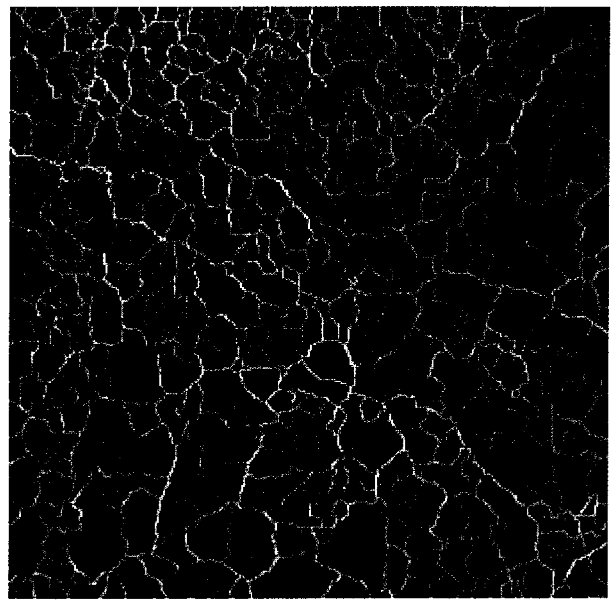

Fig 3 : Result of the watershed process

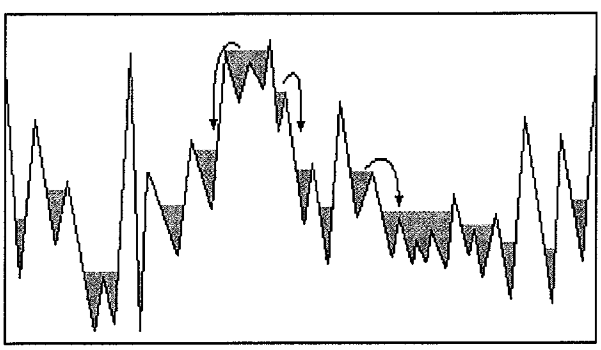

Fig 2 : Schema of the flooding process applied to a one-dimension signal. The grey zones represent the water poured into the basins, eliminating small peaks due to noise. The arrows show the water falling from the overloaded basins into lower ones, through the settle points

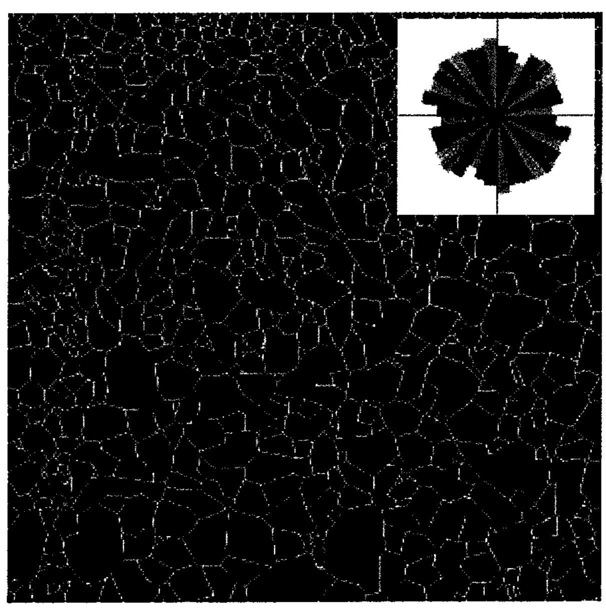

Fig 4 : Polygonal approximation (following the second run). The upper right corner shows the distribution of directions of the edges. The area of each sector is proportional to the number of edges having its orientation. The mean area of the polygons is 5 km^2, their mean diameter is 2.6 km